REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

(2)

1. AGENCY USE ONLY (Leave blank)	3. REPORT TYPE AND DATES COVERED FINAL 15 Jun 89 - 14 Dec 91

4. TITLE AND SUBTITLE
"STATISTICAL THEORY ON RELIABILITY" (U)

5. FUNDING NUMBERS
61102F
2304/A5

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8. PERFORMING ORGANIZATION REPORT NUMBER
AFOSR-TR- 92 0358

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NM
Bldg 410
Bolling AFB DC 20332-6448

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFOSR-89-0406

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release;
Distribution Unlimited

12b. DISTRIBUTION CODE
UL

13. ABSTRACT *(Maximum 200 words)*

Considerable progress was made by the Principal Investigator Professor Asit Basu and his collaborators on the areas of tests for expotentiality, component life length estimation, sequential and influential methods, and Bayesian approaches for reparable systems. All of these results contribute to a better understnading of reliability principles and better techniques for applied reliability practice.

14. SUBJECT TERMS

15. NUMBER OF PAGES
7

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

FINAL TECHNICAL REPORT

TO THE AIR FORCE OFFICE OF

SCIENTIFIC RESEARCH

(FOR THE PERIOD JUNE 15, 1989 - DECEMBER 14, 1991)

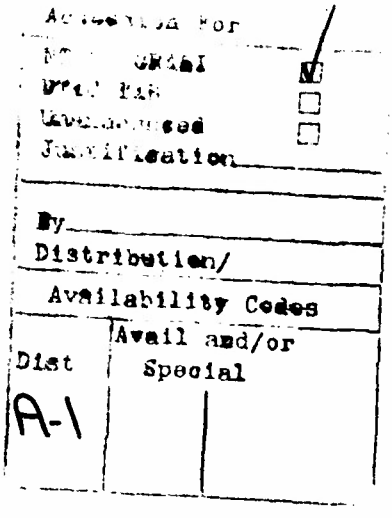
For the Research Program on

STATISTICAL THEORY ON RELIABILITY
(AIR FORCE GRANT NO. AFOSR-89-0406)

BY THE

Department of Statistics

University of Missouri-Columbia



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FINAL TECHNICAL REPORT ON AIR FORCE GRANT NO. AFOSR 89-0406 ON STATISTICAL THEORY OF RELIABILITY

The project started on June 15, 1989 and was completed on December 14, 1991. During this period the Principal Investigator, A. P. Basu, along with his collaborators (most of which were not supported by the AFOSR) considered a number of problems. We describe them below. Technical Reports and publications prepared under the project are given below along with their abstracts.

A. RESEARCH PAPERS AND OTHER PUBLICATIONS COMPLETED

1. A Note on Tests for Exponentiality by Deshpande. (by Asit P. Basu and Dipankar Bandyopadhyay). Published in Biometrika. Vol. 76 (1989) pages 403-405.

Abstract:

Recently Deshpande (1983) has proposed a class of simple tests for testing exponentiality against the increasing failure rate average class of non-exponential probability distributions. These tests have a number of desirable properties. However, they suffer from some omissions. The object of this note is to provide the missing arguments so that the paper can be more useful.

2. A Class of Tests for Exponentiality Against Decreasing Mean Residual Life Alternatives. (by Asit P. Basu and Dipankar Bandyopadhyay). Published in Communications in Statistics. Vol. 19 (1990) pages 905-920.

Abstract:

A class of tests is proposed for testing Exponentiality against Decreasing Mean Residual Life (DMRL) class of non-exponential probability distributions. These tests are consistent and asymptotically unbiased against all continuous DMRL alternatives. They are U-statistics and hence asymptotically normally distributed. The asymptotic relative efficiency (ARE) with respect to other tests for DMRL are quite high. Small sample powers are also comparable with small powers of the competitors.

3. On A Generalization of A Model by Lindley and Singpurwalla. (by Asit P. Basu and Dipankar Bandyopadhyay). Published in Advances in Applied Probability. Vol. 22 (1990) pages 498-500.

Abstract:

The flexibility of a notion considered by Lindley and Singpurwalla is pointed out. It is shown that their set-up can be generalized by looking at systems whose component life lengths are a priori dependent.

4. Two-Stage Testing Whether New is Better Than Used. (by Asit P. Basu and M. S. Alam). Published in Sequential Analysis. Vol. 9 (1990) pages 283-296.

Abstract:

A two-stage test is proposed for testing the hypothesis H_0: F is exponential versus H_1: F is NBU and not exponential, on the basis of a random sample from F. To compare the performance of the two-stage test with corresponding one sample test, powers and expected sample sizes are computed by simulation for various alternatives. It is shown that, for the two-stage test with approximately the same power, the expected sample size is considerably smaller. Critical values are tabulated to permit application of the test. Finally, an illustrative example is given.

5. Estimating the Intensity Function of A Power Law Process at the Current Time: Time Truncated Case. (by Asit P. Basu and Steven E. Rigdon). Published in Communications in Statistics Simulation and Computation. Vol. 19 (1990) pages 1079-1104.

Abstract:

The power law process, a nonhomogeneous Poisson process with intensity function $u(t) = (\beta/\theta)(t/\theta)^{\beta-1}$, is frequently used to model the occurrence of events in time. Often, an important quantity is the value of the intensity function at the current time, that is, the time when data collection is ceased. In this article, the problem of estimating this quantity is addressed when the data are time truncated, that is, when data collection is stopped at a predetermined time T. The class of multiples of the conditional MLE is suggested, and some members are analyzed. In addition, the class of estimators formed by first performing a preliminary test of significance on the parameter β is analyzed. Expressions for the bias and MSE of these estimators are derived and evaluated for several values of the parameters.

6. A Repeated Significance Test for New Better Than Used. (by Asit P. Basu and M. S. Alam). Published in Sequential Analysis. Vol. 9 (1990) pages 317-325.

Abstract:

In this paper we develop a nonparametric repeated significance test for testing the hypothesis H_0: F is exponential versus H_1: F is NBU and not exponential on the basis of a random sample $X_1,\ldots,X_n$ from F. Asymptotic distribution of the test statistic under null hypothesis is obtained. Also asymptotic distribution under local alternatives and the power of the test are considered, and the efficiency of a repeated significance test as compared to a conventional terminal test based on the target sample size is discussed.

7. Sequential Methods in Reliability and Life Testing. (by Asit P. Basu). Invited Paper. Handbook of Sequential Analysis. Vol. 9 (1991) pages 581-592.

Abstract:

A survey of sequential procedures in the area of reliability and life testing is given. Considerable work has been done in this field. Since the pioneering work of Wald (1974), a number of books and monographs on sequential analysis have been published. Also a number of books on reliability theory contain materials on sequential analysis in reliability or survival analysis. See, for example, the books by Ghosh (1970), Mann, Schaffer, and Singpurwalla (1974), Sen (1981), and Wetherill (1975). Here we survey some recent developments. In Section 2 we discuss sequential procedures for the exponential distribution. Other parametric models are considered in Section 3. Sections 4 and 5 deal with sequential probability ratio tests for availability and reliability. Finally two-stage and repeated significance test procedures for distributions with aging concepts are given in Section 6.

8. A Survey of Some Inference Problems For Dependent Systems. (by Asit P. Basu). Invited Paper. IMS Lecture Notes on Topics on Statistical Dependence. (1991) pages 35-44.

Abstract:

In this paper a survey of some inferences problems relating to dependent systems are considered. A number of multivariate models, both parametric and nonparametric, are given and related tests of dependence and tests of exponentiality are considered.

9. Bayesian Approach to Life Testing and Reliability Estimation Using Asymmetric Loss Function. (by Asit P. Basu and Nader Ebrahimi). Journal of Statistical Planning and Inference. Vol. 29 (1991) pages 21-31.

Abstract:

In this paper we derive bayes estimators of the mean lifetime and the reliability function in the exponential life testing model. The loss functions used are asymmetric to reflect that, in most situations of interest, overestimating is more harmful than understanding. A number of prior distributions have been considered and Bayesian estimates have been compared with corresponding estimates with squared error loss function.

10. Bayesian Approach to Some Problems in Life Testing and Reliability Estimation. (by Asit P. Basu and Nader Ebrahimi). To appear in the Proceedings of Indo-US Conference on Bayesian Statistics.

Abstract:

In this paper a survey of some inference problems relating to the exponential distribution is presented. Among the problems considered are: (1) estimation of parameters of exponential distribution using asymmetric loss function; and (2) reliability estimation of complex systems. Parametric empirical Bayes methods for the estimation of failure processes for repairable systems are also given.

11. Repairable Systems: Concepts and Results. (by Asit P. Basu and Steven E. Rigdon). ASQC Quality Congress Transactions. (1991) pages 84-90.

Abstract:

Quality and reliability are closely related concepts; they go hand in hand. To continue the "quality revolution" we need to have a "reliability revolution" also. "Probabilistic modeling and statistical analysis by themselves cannot directly contribute to improving reliability. Only making design changes, improving quality control, screening out defective parts, etc., can actually increase reliability. Modeling (analysis), however is the quickest way of showing - or appearing to show - that an item will meet (has met) its reliability requirements; such techniques are also very useful in deciding what needs to be done to make an item more reliable." (Ascher and Feingold (1984)). To this end it would be desirable to have a clear idea of exactly what is to be used and when. The purpose of this paper is to clarify some concepts and issues in the area of reliability. In studying reliability of complex systems there appears to be considerable confusion among engineers and scientists as to how various terms are defined, and how an appropriate model can be chosen in a specific context. Also methodologies appropriate for studying nonrepairable systems are sometimes mistakenly used for studying repairable systems, that is, items which are repaired after successive failures over time. In contrast, items in nonrepairable systems fail only once, and are then discarded. We first clarify various concepts such as failure rate, intensity rate, intensity function, Weibull process, power law process, etc., separately for repairable systems and nonrepairable systems. Next we define the power law process as a model for repairable systems and describe its properties. Inference procedures are briefly given. Finally, a number of illustrative examples are given.

12. Life Testing and Reliability Estimation Under Asymmetric Loss. (by Asit P. Basu and R. D. Thompson). To appear in Survival Analysis and Related Works. (Proceedings of NATO Conference).

Abstract:

In this paper the problem of estimating reliability functions (survival functions) is considered. A survey of some recent results using both asymmetric loss and squared-error loss is presented assuming an underlying negative exponential survival model. For illustration purposes, conjugate families of prior distributions are used.

13. On A Test Exponentiality Against Monotone Failure Rates. (by Asit P. Basu)

Abstract:

In this paper we consider a survey of some recent results for a test for exponentiality against increasing failure rate average class of nonexponential probability distributions. Various extensions of this test, including multivarite extension, are considered. In Section 2 some parametric exponential models are given. IFR and IFRA distributions are next discussed in Section 3. Deshpande's test is presented in Section 4 and its two-stage extension is given in Section 5. Also a test for bivariate exponentiality is presented in Section 6.

14. Reliability Growth Estimation With Missing Data-1. (by Asit P. Basu and Larry Crow)

Abstract:

In reliability literature the homogeneous Poisson process (HPP) has been used extensively as a model. However, in repairable systems that deteriorate (or improve over time) a nonhomogeneous Poisson process (NHPP) is found to be a more appropriate model. The model is also useful as a model in studying reliability growth and software reliability.

15. A Class of Tests for Bivariate Exponentiality Against Bivariate Increasing Rate Alternatives. (by Asit P. Basu and Dipankar Bandhopadhyay). Published by Journal of Statistical Planning and Inference. Vol 29, pages 337-349.

Abstract:

A class of tests if proposed for testing bivariate exponentiality against the bivariate increasing failure rate class of probability distributions. These tests are consistent and asymptotically unbiased against all continuous bivariate increasing failure rate alternatives. They are U-statistics and hence asymptotically normally distributed. Numerical evaluation of critical values and small sample powers of some selected tests have been done using Monte Carlo simulation.

B. OTHER INVITED PUBLICATIONS AND CREATIVE ACTIVITIES COMPLETED UNDER AFOSR GRANT

Edited, Special Reliability Issue of the Journal of Statistical Planning and Inference. (1991) Vol. 29, Parts 1 and 2.

Book Review. The Inverse Gaussian Distribution by Chhikara and Folks. Technometrics (1990).

Organized International Research Conference on Reliability at The University of Missouri-Columbia, Mo., June 1991.

Invited paper presented at the NATO Advanced Research Workshop on Survival Analysis and Related Topics at the Ohio State University, June 1991.

Invited paper presented at the annual meeting of the American Statistical Association, Atlanta, Georgia, August 1991.

Presented paper at the conference on Bayesian Statistics in Science and Technology at the Carnegie Mellon University, Pittsburgh, PA., September 1991.

Presented a paper at the Bayesian Workshop on Statistics at the Massachusetts Institute of Technology, Boston, November, 1991.

Established contact with Rome Air Development Center and the USAF School of Aerospace Medicine for possible future research.

C. CONCLUDING REMARKS

During this project a number of important problems have been considered. The present project identified a number of important problems, including possible research projects with RADC, New York and USAF School of Aerospace Medicine, Texas. The PI is looking forward to work on these projects with future AFOSR grants.